

THE INCREDIBLE DIVERSITY OF FE-BEARING PHASES AT GUSEV CRATER, MARS, ACCORDING TO THE MARS EXPLORATION ROVER MÖSSBAUER SPECTROMETER. R. V. Morris¹, G. Klingelhöfer², C. Schröder², D. S. Rodionov^{2,3}, D. W. Ming¹, and A. Yen⁴. ¹NASA Johnson Space Center, Houston, TX, USA 77058 (richard.v.morris@nasa.gov), ²Johannes Gutenberg-Universität, Mainz, Germany, ³Space Research Institute IKI, Moscow, Russia, ⁴Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Introduction: The Mars Exploration Rover (MER) Spirit landed on the plains of Gusev Crater on 4 January 2004. One primary scientific objective for the mission is to characterize the mineralogical and elemental composition of surface materials, searching for evidence of water and clues for assessing past and current climates and their suitability for life [1]. The role of the Mössbauer (MB) spectrometer on Spirit is to provide quantitative information about the distribution of Fe among its oxidation and coordination states, identification of Fe-bearing phases, and relative distribution of Fe among those phases. The speciation and distribution of Fe in Martian rock and soil constrains the primary rock types, redox conditions under which primary minerals crystallized, the extent of alteration and weathering, the type of alteration and weathering products, and the processes and environmental conditions for alteration and weathering. In this abstract, we discuss the incredible diversity of Fe-bearing phases detected by Spirit's MB instrument during its first 540 sols of exploration at Gusev crater [2,3].

Gusev Crater Plains: During the first ~150 sols, Spirit roved eastward across the plains from its landing site to the Columbia Hills. Analyzed rocks are unweathered to weakly weathered olivine basalt, with olivine, pyroxene (Ol > Px), magnetite (Mt), and minor hematite (Hm) and nanophase ferric oxide (npOx) as their primary Fe-bearing minerals (Fig. 1a). Soils are generally similar basaltic materials (Figs. 1b and 1c), except that the proportion of npOx is much higher (up to ~40%). npOx is an oct-Fe³⁺ alteration product whose concentration is highest in fine-grained soils and lowest in rock interiors exposed by grinding with the Rock Abrasion Tool (RAT); in martian soils, its concentration correlates with S and Cl. Fe³⁺/Fe_T for Gusev plains rocks and soils is 0.07-0.23 and 0.23-0.41, respectively.

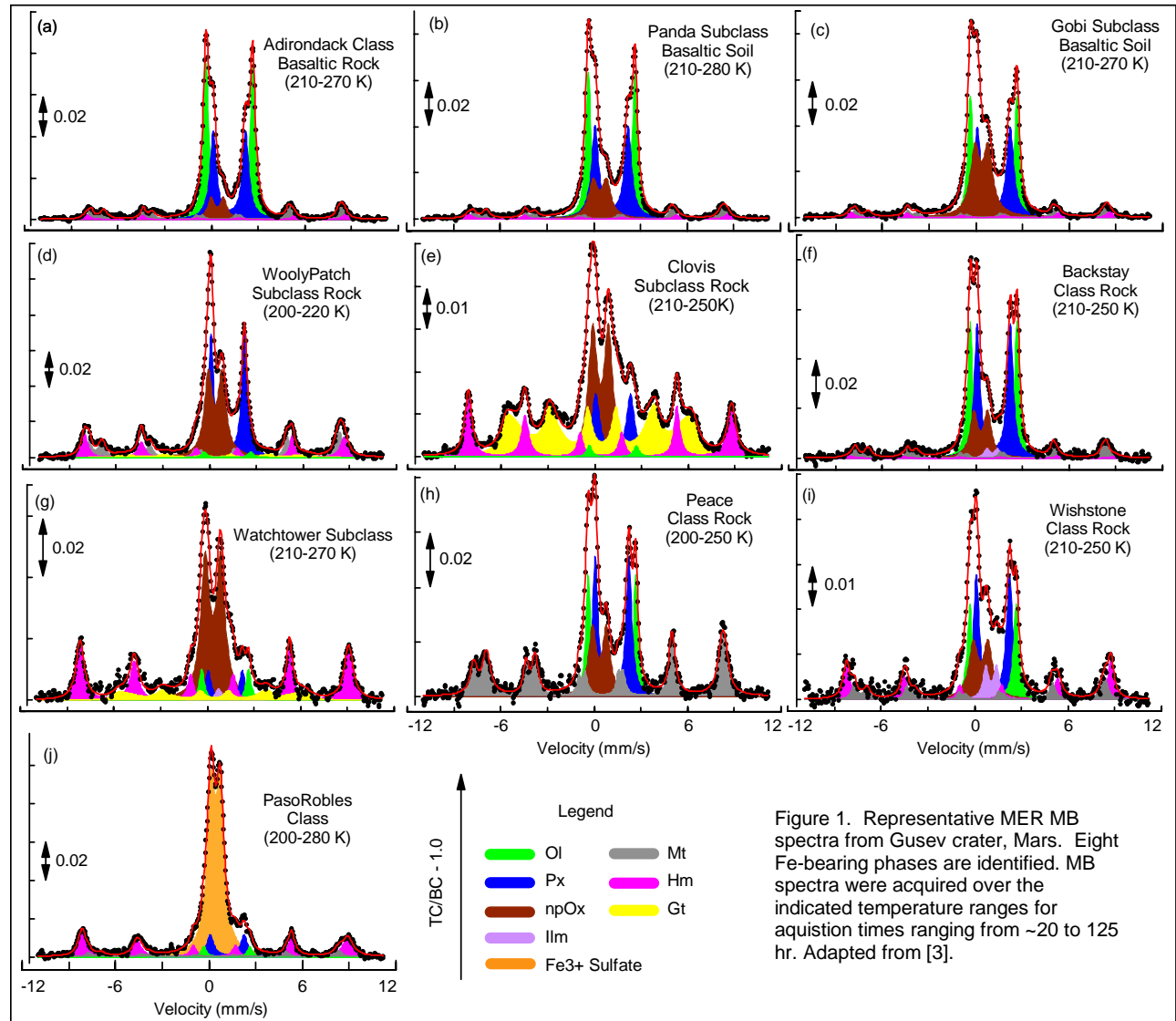
West Spur: During sols ~150-320, Spirit explored the lower slopes of the Columbia Hills (West Spur). West Spur rocks are dramatically different from those on the Gusev plains. They are highly altered, even for interior surfaces exposed by grinding (Fe³⁺/Fe_T ~0.56-0.84). High concentrations of npOx, hematite (Hm), and sometimes magnetite (Mt) are present (e.g., WoolyPatch (Fig. 1d [3]). Some rocks, particularly one named Clovis, contain significant quantities of goethite (α -FeOOH; ~40% of total Fe) (Fig. 1e). The detection of goethite is very significant because it is a mineralogical marker for aqueous alteration.

Husband Hill: For sols ~320-540, Spirit explored Husband Hill in the Columbia Hills. This hill is characterized by both unaltered and highly altered outcrop rocks (Fe³⁺/Fe_T ~0.31-0.94) and scattered occurrences of unaltered float rocks (Backstay (Fig 1f) with (Fe³⁺/Fe_T ~0.23). Most outcrop rocks (e.g., Watchtower and Paros (Fig. 1g) are highly altered, with high concentrations of Hm and npOx. Only Peace outcrop, which has large quantities of Mt (~34% of total Fe) (Fig. 1h), is unaltered according to MB, although it appears to have a magnesium sulfate cement [4,5]. Ilmenite is detected in Wishstone, Watchtower, and related rocks (up to ~8% of total Fe) (Fig. 1i).

With one exception, soils in the Columbia Hills are basaltic with the same general MB mineralogical composition as those on the Gusev plains (Fig 1b and 1c). The one exception is

PasoRobles soil. Its MB spectrum is characterized by a oct-Fe³⁺ doublet whose quadrupole splitting is narrower than that for any other soil (Fig. 1j). The concentration of S in this sample is the highest reported on Mars to date (31.6% SO₃ [4]), implying that the doublet is associated with a ferric sulfate.

Summary: Through sol 540, the Mössbauer spectrometer on the Spirit rover has identified 8 Fe-bearing phases on Mars: olivine, pyroxene, magnetite, ilmenite, npOx, hematite, goethite, and probable Fe³⁺-sulfate. Goethite and Fe³⁺-sulfate are mineralogical markers for aqueous processes, likely under acid sulfate conditions. The presence of magnetite in both rock and soil establishes the mineral as a magnetic phase in martian soil and rock.



References: [1] Squyres et al., *Science*, 305 (2004) 794. [2] Morris et al., *Science*, 305 (2004) 833. [3] Morris et al., *J. Geophys. Res.* 111, (2006) E02S13, doi:10.1029/2005JE002584. [4] Gellert et al., *J. Geophys., Res.* 111 (2006) E02S05, doi:10.1029/2005JE002555. [5] Ming et al., *J. Geophys. Res.*, 111 (2006) E02S12, doi:10.1029/2005JE002560.